Science and Technology Committee Panel

Converging Research on +Gz-Induced Loss of Consciousness

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The G-induced loss of consciousness (G-LOC) hazard can be reduced either by preventing its occurrence or shortening the period of incapacitation. The latter requires an understanding of this period of incapacitation. Two types of G-LOC occur: Type I is short duration and without convulsive type movements; and Type II is longer and with convulsions. Psychological suppression (denial) by pilots that G-LOC had occurred appears to be an important problem in reporting surveys and flying safety. Auditory and visual types of sensory stimuli to reduce the period of incapacitation are discussed. Recognition by the pilot that G-LOC has occurred appears to decrease incapacitation times and should be considered part of G training. Methods of developing an aircraft recovery system after G-LOC has occurred in pilots is considered a viable approach and is examined. Converging on the G-LOC problem by both, reducing its incidence as well as its duration appears to offer an additional dimension in the approach towards solving this important operational problem.

EVER SINCE LOSS of consciousness was recognized as an aviation-related hazard, the focus of the aeromedical research community has been on prevention. $+G_z$-induced loss of consciousness (G-LOC) prevention methods have been aimed at enhancing $+G_z$ tolerance by increasing the $+G_z$ level achievable and extending the period of time at $+G_z$. Recent aircraft mishaps and inflight incidents have adequately demonstrated that G-LOC continues to be a significant aviation problem. Aerospace engineering enhancement of aircraft capabilities has proceeded, and promises to continue, at a more rapid rate than the aeromedical research community's ability to provide adequate protection for the aircrew piloting these aircraft. It remains the responsibility of aeromedical research to assure maximum safety and performance of fighter aircraft aircrews. Utilization of the full potential of a weapon system should not be limited by the vulnerability of the human operator. Even if the traditional research approach does provide methods to enhance tolerance, G-LOC will have a finite potential for occurrence as long as there is a heart-to-eye differential in the G-field. (2).

Recent research has begun to focus on the G-LOC phenomenon itself (8). Although earlier research qualitatively describing G-LOC does exist, little research on quantitating various aspects of G-LOC is available. The incapacitation period resulting from exceeding one's $+G_z$ tolerance was investigated in our initial work and found to be approximately 15 s (10). It was evident that this was probably the minimum time of G-LOC incapacitation that could be expected, since the 15-s measurement represented only the unconscious period. A period of confusion and disorientation followed the period of unconsciousness lengthening the overall incapacitation of G-LOC. Research at the Naval Air Development Center measured both the period of unconsciousness (absolute incapacitation) and the following period of confusion and disorientation (relative incapacitation) (4). A continuation of our efforts utilizing a master caution light and auditory tone to accurately define the absolute, relative, and total (sum of absolute and relative) incapacitation revealed results in close agreement with the similar studies performed by the Navy (7). The time of incapacitation resulting from G-LOC has been shown to be dependent on the $+G_z$ onset rate, incapacitation periods being longer for the gradual onset exposure as compared to rapid onset exposures. The rapid onset of $+G_z$ is more closely associated with operational $+G_z$ exposure experienced inflight; however, the comparison of the differences between the incapacitation resulting from the differential onset of $+G_z$ is very important in understanding the mech-

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TABLE I. USAFSAM G-LOC INCAPACITATION TIMES.

Group	N	Incapacitation(s)		
		Absolute	Relative	Total
All	55	16	15	31
GOR	34	19	16	35
ROR	21	12	12	24
Type I G-LOC	38	15	13	28
Type II G-LOC	17	20	17	37

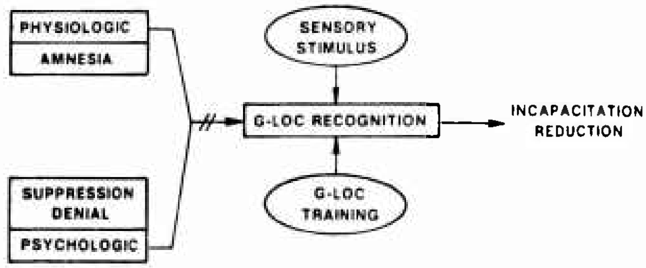

Fig. 1. G-LOC recognition and recovery.

anism and factors that affect G-LOC incapacitation. Our G-LOC incapacitation times are given in Table I.

The physiologic effects (greyout, blackout, and unconsciousness) associated with reaching and exceeding one's $+G_z$-tolerance limit represent a continuum resulting from deprivation of blood flow to the central nervous system. G-LOC results from lack of blood flow to the brain. Analysis of a very large number of G-LOC episodes revealed that there are at least two distinct types of G-LOC responses. The separation into these two types (Type I and Type II G-LOC) provides a workable classification of the level of central nervous system embarrassment and the nature of the symptoms which can be expected. Type I G-LOC is characterized by a short duration and the absence of convulsive type movements. The prolonged unconscious episodes with associated convulsive movements (flail) and, frequently, recognizable dream-like states are more catastrophic or Type II G-LOC episodes. Certainly Type II G-LOC represents a greater threat to aviation safety. The incapacitation times for Type I and Type II G-LOC are given in Table I.

Documentation of the physiologic symptoms resulting from G-LOC revealed that the episodes are extremely difficult to recognize. The G-LOC associated symptoms of tingling in the extremities and face (perioral numbness), convulsive (flail) movements, and a feeling of falling asleep or dreaming are, therefore, of critical importance for enhancement of aircrew recognition of inflight G-LOC. In addition to the physiologic sequelae resulting from G-LOC, a study of recurrent G-LOC episodes documented the psychologic symptoms following G-LOC (9). The psychologic suppression (denial), along with physiologic amnesia, results in a two-fold problem for G-LOC recognition (Fig. 1). Typical characteristics of the combination of these physiologic and psychologic mechanisms have been documented from inflight G-LOC (3). Complete aircrew familiarization with the physiologic/psychologic symptom complex is essential for enhancement of G-LOC recognition and reporting and for safety.

The data for G-LOC analysis comes from controlled centrifuge experiments. The available data from inflight G-LOC episodes gives every indication that the centrifuge results are directly applicable (1). The other experimental data which has direct importance is the experimentation on acute arrest of cerebral blood flow at ground $(+1G_z)$ level using a cervical occlusion cuff (6). The incapacitation period resulting from these occlusion experiments provides the so-called "gold standard" which could be obtainable by optimizing various conditions that result in enhanced recovery. From all indications, the minimum time of total incapacitation resulting from unconsciousness could approach 7 s. Certain aspects of $+G_z$-exposure could potentially prolong the lack of adequate circulation and the resulting incapacitation period, including the finite period of offset of the G-force which prevents immediate return of blood flow to the brain. The current strategy for decreasing the incapacitation period is aimed at reduction of the relative incapacitation period.

Sensory stimuli show promise in decreasing the relative incapacitation period. Sensory stimuli, such as the visual/auditory stimuli, used in measuring G-LOC incapacitation have been definitely proven to be significant in enhancing G-LOC recognition. Optimum sensory stimuli which could maximize G-LOC recognition, however, have yet to be fully evaluated. Such stimuli would not only maximize G-LOC recognition, but could be significant factors in reducing the relative incapacitation period. An auditory stimulus has been demonstrated to be more effective than a visual stimulus; however, optimum methods to enhance recovery have yet to be systematically evaluated.

The total incapacitation resulting from G-LOC is made up of absolute and relative incapacitation. The absolute incapacitation period is probably physiologically determined and is not as variable. The relative incapacitation is more variable and is dependent on the level of G-LOC experience of the individual. An individual with G-LOC experience is able to recognize the unconsciousness and re-orient to the situation much more rapidly than an individual who experiences an initial G-LOC episode. In fact, even individuals who have had more than one G-LOC episode have been able to improve their ability to re-orient, thus decreasing the relative incapacitation period. The potential ability to decrease the relative incapacitation, hence total incapacitation reduction, provides the basis for consideration of exposing anyone who enters the high $+G_z$ environment to an orientation to G-LOC. Recognition of the unique individual symptoms resulting from G-LOC could, therefore, decrease the relative incapacitation period and improve survival should inadvertent G-LOC occur inflight. The sensory stimuli found to enhance G-LOC recognition, and which may decrease overall incapacitation, should be used in G-LOC training and eventually incorporated into the aircraft. Experiencing G-LOC as a part of G-training could be accomplished, and from existing experimental evidence may be carried out safely.

Autorecovery of fighter aircraft following G-LOC (or other types of sudden but temporary incapacitation) to avoid ground collision has become reality (5). Problems may be foreseen regarding pilot acceptance of computer usurpation of aircraft control and the hesitation to fully pursue autorecovery technology because it may not be

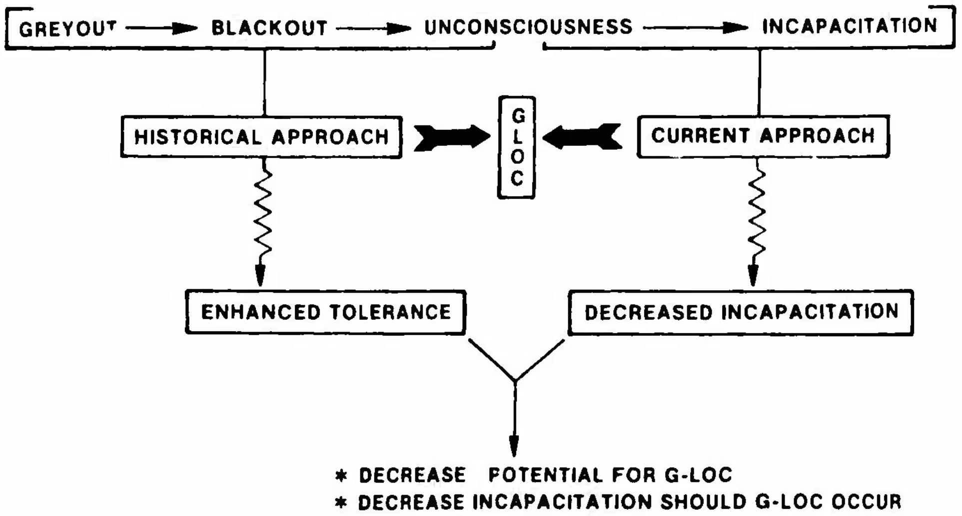

Fig. 2. Convergent G-LOC research.

considered to be capable of recovering aircraft from 100% of the envisioned scenarios. Autorecovery may proceed along at least two pathways: (1) critical flight parameter monitoring without any physiologic monitoring of the aircrew; and (2) physiologic monitoring integrated with flight parameter monitoring. Either way, autorecovery technology should include mechanisms to decrease overall incapacitation and enhance pilot situational awareness upon recovery. Not only safety but effective weapon system employment requires the most rapid transition of the aircrew from an incapacitated state into complete re-orientation and a maximum performance state. The physiologic aspects of aircraft autorecovery include both monitoring of the aircrew for determination of acute incapacitation and the presence of sensory stimuli to enhance the recovery process. G-LOC certainly is a prime candidate for autorecovery technology.

In summary, G-LOC will remain a potential threat for aircrew utilizing advanced aircraft maximum maneuverability. Traditional research efforts continue toward providing optimum G-LOC prevention. Additional avenues may be available for enhancing flight safety by detailed investigation of the unconsciousness state and subsequent recovery. These approaches include decreasing the total G-LOC incapacitation period and enhanced restoration of aircrew situational awareness post G-LOC. Research in this direction has the additional potential for revealing new methods of primary G-LOC prevention through a better understanding of the physiologic aspects of unconsciousness. Converging on the G-LOC problem (Fig. 2) not only leads to the decrease potential for G-LOC, but in addition would decrease aircrew incapacitation should it inadvertently occur.

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